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Principles of General Covariance
and the

Role of Coordinates in General Relativity

Semi-Annual Report

January 1964

James L. Anderson



STEVENSON INSTITUTE
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During this period we have continued our investigation of the role of coordinates and coordinate conditions in physics. Two separate sub-investigations were undertaken and are described below.

As a preliminary to a study of the role of coordinate conditions in the derivation of the equations of motion in general relativity we investigated the analogous role of gauge conditions in electrodynamics and their bearing on the interactions of charged particles in that theory. For this purpose we developed a method of obtaining a Fokker action for these charges which follows from the combined action for the electromagnetic field plus particle action in an unambiguous manner. In the usual derivation certain surface integrals arise which are neglected in order to obtain the correct Fokker action. By using an action for the total system, field plus particle, which differs from the usual action for this system by a complete divergence these surface terms do not arise. One can then derive a form for the Fokker action corresponding to different gauge conditions. When one uses the Lorentz gauge one obtains the usual retarded interaction between the various current four vectors. With the Coulomb gauge one obtains two terms, an instantaneous Coulomb-type interaction between the charge densities plus a retarded interaction between the transverse currents. With this form of the interaction one obtains very simply the Breit formula for the interaction of moving charges. Higher order corrections in v/c to this formula are also readily obtained. It appears that in the gravitational

case the use of a Lorentz-type coordinate condition is most suited to a fast-motion approximation while a Coulomb-type coordinate condition works best for an EIH slow-motion approximation. As a consequence the relation between these two approximations can be readily exhibited. The details of this work are now being prepared for publication.

The relationship between a mathematical coordinate system and a physical reference frame has also been investigated. Using a model of a light clock devised by Wheeler and Marzkie we constructed a model of an inertial frame in special relativity. The existence of this frame is independent of the coordinate system used to describe this frame. If one used a Minkowski coordinate then there exists a linear relation between these coordinates and physical intervals in the inertial frame. For other coordinate systems as such, simple relation exists. We have also constructed several examples of an accelerated reference frame in special relativity. We plan to use these frames to discuss the principle of equivalence in what we hope will be an unambiguous manner. These investigations also have lead to a reexamination of the measurement of time intervals and the interpretation of the proper time between two points on a world-line. These studies will form the basis of an investigation of the problems which arise when one brings in the quantum restrictions on space-time measurements.